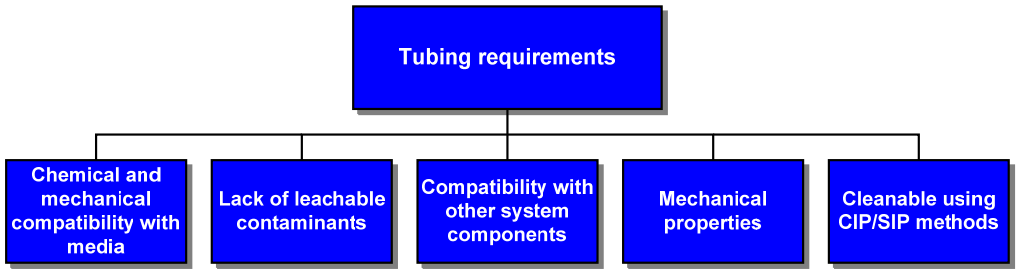
Critical Fluid Handling

Introduction

Tubing has become so ubiquitous in the industrial sector that it is sometimes taken for granted. Soft tubing manufactured from reinforced PVC is used for large bore compressed air and water hoses, while stiffer PA (nylon) hoses are used for compressed air actuator tubing. These tubes are used to carry fluids and gases for many common applications and at the same time, they are essential components in many leading-edge technologies as well. In these cases, the effect of the tube on the fluid, or vice versa, can be critical for a successful application. This month's Technical Newsletter discusses some of the areas where critical fluid handling is, well, critical.

Materials requirements

The primary aim of critical fluid handling is to transport uncontaminated fluids. Any tubing that is used must protect the fluid from contamination, either from external sources or from the tubing itself. Limiting contamination is often called materials integrity management. Critical fluid handling means different things to different people and in most cases its characterization depends on the specific application. There are, however, some common requirements that tubing must meet for critical fluid handling applications. These are shown below:



Industries involved in critical fluid handling

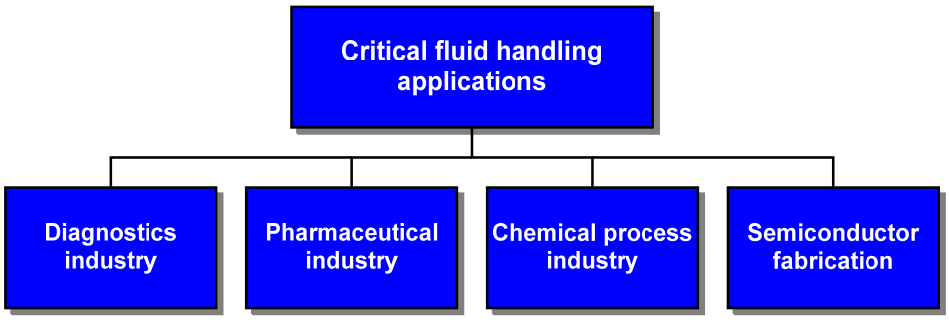
- The base tubing material must be compatible with the fluid that is being carried. This means that the tubing material must be resistant to any changes in mechanical or chemical properties after prolonged exposure to these fluids. Not only that, but the tubing must also be mechanically resistant to the media and not suffer from any degradation of mechanical properties after contact. The aggressive media used in some applications make this an especially important requirement.
- The tubing material must not contain any additives capable of leaching out into the fluid being carried. In the case of some aggressive fluids, this precludes the use of many plasticizers typically used to soften materials.

- The tubing material must also be compatible with all other materials used in the fluid handling system. This is particularly relevant in areas where tubing comes into contact with other materials.
- The tubing material must have the required mechanical properties to maintain system integrity. This is important in semiconductor fabrication where the tubing is required to transport corrosive fluids at high temperatures and pressures. In other instances, critical fluids can be abrasive, and as a result, the tubing must have the required abrasion resistance to prevent contamination.
- For many applications, the tubing material must be capable of cleaning and sterilizing using clean-in-place (CIP) or steam-in-place (SIP) methods. Tubing is often very small in internal diameter, which makes cleaning by conventional methods difficult. Even de-ionized and ultra-pure water will allow the formation of biofilms after a very short time. Without regular cleaning, biofilm deposits can later be stripped from the tubing walls to contaminate the transported fluid and other downstream elements of the system. The formation of biofilms is affected by the surface finish and surface chemistry of the tubing. Ideally, the tubing should have a very low chemical reactivity to reduce the initial formation of biofilms. Even if these deposits do form, CIP and/or SIP provide a quick and reliable cleaning solution of any that do form.

These basic requirements are not easily met and many of the common plastic tubing materials are often unsuitable for critical fluid handling applications.

Industries

The variety of application areas that can be deemed ‘critical fluid handling’ is high but several areas are obvious as being particularly demanding for tubing and should be covered in more detail, these are shown below:



Industries involved in critical fluid handling

- **Diagnostics** - The quality and specification of tubing used in clinical and diagnostic applications is often critical to the performance of much more expensive equipment. Tubing is used for applications such as sampling, reagent transfer, dialysis, blood processing, and washing.

- **Pharmaceutical and food industries** - Tubing for this type of application has both high purity and high hygiene requirements. The introduction of any contaminants can have an adverse effect on the pharmaceutical/food or the patient/consumer and must be rigorously avoided. Products for this type of application are considered to be hygiene critical and CIP is generally an essential requirement

- **Semiconductor fabrication** - The fabrication of semiconductors requires extreme purity and is in many ways the ultimate in demanding critical fluid handling. Contamination control can make the difference between high and low wafer yields and determine the profitability of the fabrication plant. Very small amounts of contamination from the tubing (at the trace amount level) can significantly reduce the productivity of the fabrication plant especially as semiconductors are shrinking in size and increasing in complexity. Any tubing carrying chemicals or water must not only be of high purity but also resistant to corrosion by the chemicals being used by the processes.

- **Chemical process industry** - The chemical process industry uses high purity fluids that are not only critical in terms of contamination avoidance but many of the fluids being transported are highly aggressive and can attack many conventional plastics to cause premature failure through processes such as environmental stress cracking (ESC).

- **Peristaltic pumps** - Many of the industries listed uses peristaltic pumps to transport critical fluids without risking contamination of the fluid by contact with normal pump parts. Peristaltic pumps avoid any risk of contamination from external elements but they place special demands on the pump tubing in terms of resilience and compression set. The tubing used must be extremely resilient to enable the peristaltic pump to continue to function accurately for a reasonable length of time.

Typically, industry requirements are diverse, making it difficult to meet every requirement in terms of compatibility, contamination, mechanical properties, and cleanability.

Materials selection

The selection of the base material for a critical fluid handling application is, as with any other plastic application, extremely important. Stainless steel has been a mainstay of the critical fluids handling industry for many years, but now there have emerged four main categories of polymers that have proven to be very capable. Each of these polymer classes contains specific performance attributes, and they are:

- **FEP (Fluorinated ethylene-propylene)**
  FEP is a fully-fluorinated copolymer made by polymerizing TFE and hexafluoropropylene. It was the first commercially-produced material to combine the unique mechanical and chemical properties of PTFE with the melt-processability of more conventional polymers. FEP has very similar mechanical and chemical properties to PTFE, but its maximum service temperature is about 100^{o}F lower. FEP has good chemical resistance, low gas and vapor permeability, excellent transmission of UV rays and is thermoformable.

- **PFA (Perfluoroalkoxy)**
  PFA was first produced in 1972 and is also melt-processable. In many ways PFA is similar to FEP because of its better mechanical properties at higher temperatures and a higher maximum service temperature. It is considered by some to be the best melt-processable fluoropolymer alternative to PTFE and the material of choice for the semiconductor and critical fluid handling markets. PFA has excellent chemical resistance, low metallic extractable characteristics, low gas permeability, and maintains good mechanical strength at high temperatures.

- **THV Tubing**
  THV is a terpolymer of tetrafluoroethylene, hexafluoropropylene and vinylidene fluoride. THV is the most flexible fluoropolymer available and has the highest degree of optical clarity. THV is easily weldable, has good chemical and environmental resistance, a high limiting oxygen resistance, is thermoformable, and has good UV transmittance.

- **PEEK Tubing**
  PEEK was one of the first designer plastics when it was introduced in 1977. It is generally regarded as being the best performing available thermoplastic and provides superior heat resistance. PEEK has excellent mechanical properties (tensile strength and burst pressure), outstanding chemical resistance and is regarded as an ideal replacement for stainless steel in many critical fluid handling applications and HPLC analytical markets.

Production requirements

Tubing that distributes critical fluids must meet demanding criteria such as:

- The tubing must be produced to consistent and tight tolerances for both the ID and the OD to ensure consistent fluid volume and flow rates, with long lengths also very important. The general tolerances should be +/- 0.001” for small tubing (up to 0.0125”) and +/- 0.003” for larger tubing (up to 0.5”).

- The tubing must have smooth inner walls. This reduces turbulent flow in the fluid and prevents dead spots or areas where biofilms can develop. This is also a requirement of the complete fluid handling system, where the system should provide a smooth, fluid flow path with no dead spots or crevices or, in the case of products to be used with blood, where blood clotting can take place.

- The tubing should be produced under clean room conditions, with Class 10,000 as an optimal environment.

- If cut to length before shipping, the tubing must be cut cleanly with no possibility of swarf, dust, or other material. Double polybagging and end-caps are common packaging procedures to ensure quality and integrity.

- The tubing should be appropriately packaged to prevent any transit contamination or damage; this may require double packaging.

- The tubing should be capable of contaminant free marking (such as laser identification) to enable both size identification and to comply with traceability requirements (only for high-purity PFA).

Summary

Critical fluid handling is an essential component when dealing with services and products ranging from high technology microchips to life-saving dialysis equipment.

For over 40 years, Zeus has partnered with customers from around the world to develop and execute high-performance polymer extrusions for the most demanding fluid handling applications. Furthermore, Zeus meets every benchmark of the critical fluid handling industry, from the resins and extrusions, purity and quality standards, to technical support and supply security. We are committed to being a top tier supplier, with the capabilities and capacity demanded by customers.